The Commission indicated that, within the NRM, they are seeking comments on this position. This section provides comments from IWG-3.

4.2.2.1 Requirements for Use of 5 GHz Band

As outlined above, three of the RDSS/MSS applicants propose to use portions of the 5150-5216 MHz band for feeder links in the space-to-Earth direction. These applicants have agreed that they can share the same spectrum for feeder links and will develop any necessary sharing arrangements amongst themselves.

Use of the 5150-5216 MHz band in the space-to-Earth direction would enable the use of C-band feeder links as well as avoid coordination difficulties with fixed-satellite service operations. In addition, coordination in general would be minimal because the band is lightly used in the United States and worldwide. It is noted that the aviation community believes that there may be difficulty using these bands outside the United States because they are allocated on a worldwide basis to aeronautical radionavigation. Such use would have to be on a non-interference basis, according to the FAA.

According to the LEO MSS applicants proposing to use the 5 GHz band, the use of C-band feeder links were chosen to complement various other features of their system proposals, including the use of relatively low cost feeder link earth stations which would be resistant to propagation factors. (IWG 3-33). These systems may require a significant number of gateway earth stations on a global basis. Thus, these applicants chose a frequency band which would minimize total earth station costs and avoid the necessity for diversity earth stations to account for propagation factors.

The applicants have limited their downlink feederlink spectrum requests to the 66 MHz currently allocated for RDSS feeder links at 5150-5216 MHz by RR 797A, compared to the 300 MHz available for 6.5 GHz uplink feeder links. An expansion of this band to 5150-5250 MHz for MSS/RDSS feeder links is desirable to allow for growth of system capacity as additional antenna beams beyond the eight per satellite assumed for RDSS are added in the L/S-bands for service links to user terminals.

4.2.2.2 Background regarding the 5 GHz Band

The band 5000-5250 MHz is allocated nationally and internationally on a primary basis to the aeronautical radionavigation service. Footnote 796 provides that the band is to be used "for the operation of the international standard system (microwave landing system) for precision approach and landing. The requirements of this system shall take precedence over other uses of this band."

Current plans for the Microwave Landing System (MLS) contemplate operations only in the 5030-5091 MHz portion of the band, and aviation spokesmen at the 1987 WARC indicated that potential future expansion of MLS would not require frequencies above 5150 MHz. As a result, 18 administrations added a national footnote allocation subject to Article 14 (Radio Regulation 797B) for primary mobile services from 5150-5250 MHz.

Footnote 797A, added at WARC-MOB-87, allocated, in certain countries (listed in Nos. 733B and 753C), subject to Article 14, the band 5150-5216 MHz to the radiodetermination-satellite service (space-to-Earth) on a primary basis. In Region 2, the band is also allocated to the radiodetermination-satellite service (space-to-Earth) on a primary basis. Footnote 797A also provides for such use, on a secondary basis, in certain countries in Regions 1 and 3. This footnote was added to accommodate a requirement of the United States for a GSO RDSS system.

Footnote 797A restricts "use by the radiodetermination-satellite service (to) feeder links in conjunction with the radiodetermination-satellite service operating in the bands 1610-1626.5 MHz and/or 2483.5-2500 MHz. The total power flux-density at the Earth's surface shall in no case exceed -159 dBW/m^2 in any 4 kHz for all angles of arrival." This PFD value was established to provide a noise to interference ratio in excess of 30 dB to an MLS receiver. (See CCIR Report 1050). Since systems other than the MLS are now being planned by the aeronautical community for this portion of the band, this PFD limit may not be applicable. In any event, this PFD limit does not address other, potentially more serious problems of interference to feeder link earth stations from aeronautical radionavigation systems being planned for the band.

4.2.2.3 Current and Planned Operations in the 5150-5250 MHz Band

The FAA opposes use of the 5150-5250 MHz band for LEO MSS feeder links. (See Letters of Gerald Markey (Attachment A) and Arnold Aquilano, Associate Administrator for Airway Facilities, FAA, Attachment B).

The FAA states that it is in the process of developing and implementing new navigation aids within the National Airspace System for this band. These include Differential Global Positioning System (DGPS), Terminal Doppler Weather Radar (TDWR) and Automatic Dependent Surveillance (ADS). The relevant characteristics of each is given in the attachments.

The band 5150-5250 MHz has been identified by the FAA for future expansion of its Terminal Doppler Weather Radar. This radar is currently being deployed within 10 nmi. of approach paths to airports. It is a critical system for predicting the occurrence of microbursts, which have proven to be threats to safe landing. This expansion plan has been accepted internationally by ICAO.

The TDWR currently is planned for 47 sites, with an additional 55 as a contractual option. The schedule for the first 47 is included in Attachment C. The technical characteristics as presented to the NTIA for Stage 4 authorization is given in Attachment D. All are planned for operation in the 5600-5650 MHz band. That band was chosen because: (1) it is properly allocated and (2) it is close to the 5150-5250 MHz band. The 5150-5250 MHz band was the first choice of the FAA. However, it was ultimately not chosen in order not to jeopardize the development of the MLS which now operates in the 5000-5150 MHz band. Expansion of the TDWR system beyond the initial 102 systems is targeted for the 5150-5250 MHz band.

In addition, the FAA has identified this band for use by subsystems of the Global Positioning System (GPS). GPS is a component of the International Civil Aviation Organization (ICAO) Global Navigation Satellite System (GNSS). These subsystems called Differential GPS (DGPS) and Pseudolites are needed to improve the inherent accuracy of the GPS signal to a level needed for precision approaches. They will use ground-to-aircraft links and will be active within about 40 nmi. of an airport.

Finally, the FAA is in the process of expanding the use of the Automatic Dependent Surveillance (ADS) concept. Currently, it is used only in transoceanic airways. Expansion of this concept to the United States and its possessions is underway. It will require both ground-to-aircraft and aircraft-to-ground links and will be operational during both enroute and terminal phases of flight.

However, as the band 5150-5250 MHz is allocated for aeronautical radionavigation, the the question was raised as to whether reallocation of the band to permit its use for meteorological aids might be required to allow its use for the TDWR system. The TDWR system operates in the 5600-5650 MHz band pursuant to the meteorological aids allocation of RR 802. The FAA is of the view that the aeronautical radionavigation allocation of 5150-5250 MHz is appropriate for TDWR because of its nature as an approach and landing aid.

4.2.2.4 Sharing Situation with the Aeronautical Radionavigation Service

One of the LEO applicants proposing to utilize the 5150-5216 MHz band for feeder links in the space-to-Earth direction submitted an analysis demonstrating its system's ability to meet the -159 dBW/m^2/4 kHz with sufficient margin for all angles of arrival (IWG3-5).

The FAA submitted preliminary technical information with regard to several services which it is considering implementing in the 5150-5250 MHz band. With regard to terminal doppler weather radars (TDWR), the FAA concludes that the proposed LEO feeder link operations most likely will not cause harmful interference, but that the operation of the TWDRs may cause harmful interference to LEO feederlinks. The level of detail available on systems which are still in the conceptual stage was not sufficient to perform a detailed interference analysis. However, a preliminary review indicates that significant interference from DGPS, ADS and TDWR into LEO MSS feeder link downlinks may occur if the FAA planned systems are implemented.

The MSS applicants have stated their willingness to work with the FCC and the FAA to locate their gateway earth stations away from airports and ground facilities where the FAA may utilize these bands. Such a geographical avoidance measure would not be useful in the case of ADS, where transmitters would be located on-board aircraft.

4.2.3 Sharing Situation Between Non-Geostationary MSS/RDSS Systems

Three LEO RDSS/MSS systems have indicated their plans to use the 5150-5216 MHz band spectrum for feeder links in the space-to-Earth direction. Because of this planned use of the same feeder link spectrum, the impact of sharing the same spectrum was analyzed.

A computer analysis of the intersection of orbits between two LEO systems was conducted in order to develop a hypothesis concerning the predicted incidence of interference that might be expected to occur when two or more LEO systems utilize the same feeder link frequencies. (IWG 3-30-Rev.1) The analysis considered two 48-satellite systems, one using polar orbits and operating at an altitude of 1020 km., and the other using circular orbits with a 47° inclination from an altitude of 1389 km. The computer simulation analyzed the angular separations between spacecraft of the two systems over a 48-hour period. This analysis identified, during a 24-hour period, only 4-5 instances, of less than one minute each, when any spacecraft from the two constellations were within a 3° angle of each other from the perspective of a ground station. Extrapolating that interference might occur during these instances, the proportion of time that interferences might be expected to occur is less than 0.5% of the time. If a third system were factored in, the total expected experience would be less than 1% of the time for each system. This is considered to be acceptable for feederlink operations of these systems because of the ability of the systems to shift traffic from one satellite to another.

In addition to the percentage of time that beam intersections occur, consideration also needs to be given to the interference levels that are experienced in the feeder links during the beam intersections. Because feeder links are typically designed to operate at a C/No + Io that is 10 or more dB higher than the service links, coordination between systems using simple frequency changing transponders and spread spectrum techniques can mitigate the interference levels encountered during beam intersections. In this regard, operations at PFD levels closer to the levels of RR 2566 than the -159 dBW/m^2/4 kHz power-flux density level specified in RR 797A will allow higher link margins to facilitate sharing of 5 GHz feeder links by multiple non-geostationary MSS/RDSS systems.

With regard to future LEO MSS systems, it is noted that all FSS spectrum is available for feeder links as an allocation matter; thus, the impact of additional systems, that may be proposed in the future, on this sharing situation in the 5/6 GHz band was not analyzed.

4.2.4 Conclusion

The Working Group recommends that the FCC identify and/or allocate suitable spectrum below 15 GHz, and preferably below 10 GHz, for MSS/RDSS feeder links. A minimum of 66 MHz is required to accommodate the three MSS/RDSS applicants that have developed system designs based on use of the 5150-5216 MHz band. A 100 MHz band for MSS/RDSS feeder links would allow for growth of system capacity as additional antenna beams beyond the eight per satellite assumed for RDSS are added in the 1.6-2.4 GHz bands for service links to user terminals. System architecture and service concepts dictate that the necessary spectrum be free of large populations of geostationary satellites and that it be possible to establish low-cost feeder link (gateway) earth stations in the United States without burdensome coordination with terrestrial services. The spectrum must also be available for use both within and outside the United States without significant international coordination restrictions because of the likely expansion of the MSS/RDSS systems to global service.

If the FCC determines that the 5150-5250 MHz band is the only spectrum below 15 GHz which can satisfy the identified MSS/RDSS feeder link requirements, the Working Group recommends that the FCC take appropriate steps with the Interdepartment Radio Advisory Committee (which includes the Federal Aviation Administration) and the National Telecommunications and Information Administration to identify conditions that could allow sharing of that band with aeronautical radionavigation.

The FCC should make appropriate modifications to the Table of Allocations in Part 2 of its Rules and appropriate modifications to Part 25 of its Rules if a change in allocations is required to make available suitable spectrum for these MSS/RDSS feeder links.

4.3 Feeder Links in Other Bands Below 15 GHz (Except 5150-5250 MHz)

In principle, any band allocated to the fixed satellite service (FSS) can be used for feeder links to non-geostationary MSS/RDSS satellites. Table 4.3 lists the FSS bands between 3 and 15 GHz that might be considered for such feeder links. Except for the 5150-5216 MHz band, the bands listed in the table are allocated to the FSS on a primary basis. Only FSS bands were analyzed because they are available for feeder links without modification to the table of frequency allocations. In this regard, both domestic and international geostationary FSS usage needs to be taken into account since non-geostationary systems would utilize feeder link bands on a worldwide basis. It should be noted that the bands for these non-geostationary MSS/RDSS system feeder links can be shared among themselves, and future non-geostationary MSS/RDSS systems can also share the same feeder link bands.

The portions of the 6425-6725 MHz bands proposed by three of the pending applicants do not appear to present any insurmountable difficulties for uplink feeder link licensing. However, as indicated in Section 4.2.2 above, such difficulties may arise with respect to the proposed use of the 5150-5216 MHz downlink band. Feeder link bands between 3 and 15 GHz are desirable for certain system configurations because of their favorable propagation conditions which reduce overall system costs compared to the next set of available FSS bands for non-geostationary MSS/RDSS feeder links at 20/30 GHz. (See Section 4.1.1). For this reason, the Working Group examined all of the other downlink bands between 3 and 15 GHz with the view of assessing their utility for feeder links to LEO MSS/RDSS satellites if the 5150-5126 MHz band is not available for such operations.

4.3.1 Allotment Planning Bands

The 4500-4800 MHz and 10.70-10.95/11.20-11.45 GHz bands are subject to the 1988 WARC FSS Allotment Plan in Appendix 30B to the international Radio Regulations. In these bands, administrations shall not change or bring into use FSS assignments except in accordance with the plan, and the plan makes no provisions for non-geostationary satellites. The FSS allotments may be used for feeder links for geostationary MSS satellites, and a portion of the United States 11/13 GHz allotment has already been assigned to AMSC. It appears that any non-geostationary MSS/RDSS satellite use of the allotment bands for feeder links would have to be on a non-interference basis under RR 342 since the allotment plan makes no explicit provisions for operations with non-geostationary satellites and only limited provisions for additional uses beyond the allotments in the plan.

Within the United States, the 4500-4800 MHz band is allocated to government fixed and mobile stations and for non-government FSS

Frequency Band	Bandwidth	Direction	Notes
3400-3600 MHz	200 MHz	downlink	No USA FSS allocation; extensive radar operations in band
3600-3700 MHz	100 MHz	downlink	Extensive radar operations in band with limited FSS use
3700-4200 MHz	500 MHz	downlink	Extensive use by geostationary FSS satellites; shared with point-to-point microwave
4500-4800 MHz	300 MHz	downlink	FSS allotment band
5150-5216 MHz	66 MHz	downlink	RDSS feeder link band pursuant to RR 797A; shared with aeronautical radionavigation and with mobile in 18 countries under RR 797B
5850-5925 MHz	75 MHz	uplink	Shared with radiolocation; limited FSS use
5925-6425 MHz	500 MHz	uplink	Extensive use by geostationary FSS satellites; shared with point-to-point microwave
6425-6725 MHz	300 MHz	uplink	Little if any use by geostationary FSS satellites; shared with point-to-point microwave
6725-7025 MHz	300 MHz	uplink	FSS allotment band
7025-7075 MHz	50 MHz	uplink	Little if any use by geostationary FSS satellites; shared with point-to-point microwave; proposed for BSS (sound) feeder links in U.S.
7250-7750 MHz	500 MHz	downlink	Government satellite band in USA; limited use by other than USA, NATO and Russia.
7900-8400 MHz	500 MHz	uplink	Government satellite band in USA; limited use by other than USA, NATO and Russia.

Table 4.3. Possible LEO MSS Feeder Link Bands

10.7-10.95 GHz	250 MHz	downlink	FSS allotment band
10.95-11.2 GHz	250 MHz	downlink	Moderate-to-heavy FSS use by geostationary satellites in Regions 1 and 3 and over oceanic areas.
11.2-11.45 GHz	250 MHz	downlink	FSS allotment band
11.45-11.7 GHz	250 MHz	downlink	Moderate-to-heavy FSS use by geostationary satellites in Regions 1 and 3 and over oceanic areas.
11.7-12.2 GHz	500 MHz	downlink	Region 2 FSS allocation; extensive use by geostationary FSS satellites; not shared with terrestrial fixed and mobile services.
12.5-12.75 GHz (Reg 1 and 3) 12.7-12.75 GHz (Reg 2)	250 MHz (Reg 1 and 3) 50 MHz (Reg 2)	uplink/downlink (Reg 1) uplink (Reg 2) downlink (Reg 3)	Moderate use by geostationary FSS satellites in Regions 1 and 3; little use in Region 2; shared with fixed and mobile services in Regions 2 and 3.
12.75-13.25 GHz	500 MHz	uplink	FSS allotment band; shared with fixed and mobile services.
13.75-14 GHz	250 MHz	uplink	Use for uplinks limited by RRs 855A and 855B due to sharing constraints with other services
14-14.5 GHz	500 MHz	uplink	Extensive use by geostationary FSS satellites; little terrestrial use of the band makes earth station siting easy.
14.5-14.8 GHz	300 MHz	uplink	Government band with no FSS allocation in USA; but designated by footnote RR 863 for BSS feeder links in Appendix 30A BSS plan.

Table 4.3. Possible LEO MSS Feeder Link Bands Continued

use on a limited basis under footnote US245. Little information is available on government use of the band. The 10.70-10.95/11.20-11.45 GHz allotment bands are non-government bands shared with point-to-point microwave stations.

The attractiveness of the FSS allotment bands is that there is little use currently planned of these bands by geostationary satellites as a practical matter.

4.3.2 Conventional FSS Bands

The conventional FSS downlink bands at 3700-4200 MHz and 10.95-11.20/11.45-11.70 MHz are available for non-government use, and can be used for feeder links to non-geostationary MSS/RDSS satellites under the provisions of RR 2613. The major problems lie in the degree of operational difficulties caused by the requirement to protect the geostationary satellite orbit and the identification of feeder link earth station sites that can be coordinated with terrestrial services. The 3700-4200 MHz band is heavily used on a worldwide basis, while use of the 10.95-11.20/11.45-11.70 GHz bands is concentrated in Regions 1 and 3 and over oceanic areas. Sharing with terrestrial services is not a problem in the 11.7-12.2 GHz band, but this band is allocated to FSS only in Region 2 and is used in Regions 1 and 3 for BSS in accordance with the BSS Plan.

4.3.3 Other FSS Bands

The other downlink bands between 3 and 15 GHz are the 3400-3600 MHz, 3600-3700 MHz, and 7250-7750 MHz bands. These bands are primarily government bands in the United States, although the 3600-3700 MHz band is available for limited non-government FSS use for international systems under footnote US245. The 3400-3600 MHz band is heavily used by government radar facilities, which makes sharing difficult, and little if any use is being made of the band for satellite service. The 7250-7750 MHz band is used by government satellite systems in the U.S. and Russia, with only limited current use by other countries. The 3600-3700 MHz band is lightly used by the FSS (e.g. Intelsat and Inmarsat). If this band is to be used for feeder links to non-geostationary MSS/RDSS systems, such feeder link earth station sites would have to be protected in the United States consistent with the intent of footnote US245.

4.3.4 Summary and Conclusions

Use of the 5150-5216 MHz band has been proposed by three of the LEO MSS/RDSS applicants for feeder links.

If this band is not available, the Commission should identify at least one other downlink band between 3 and 15 GHz that would be available for assignment for non-geostationary satellite feeder links to satisfy the feeder link requirements identified in

Section 4.1.1 above. This band would be utilized in conjunction with the proposed uplink feeder link band at 6525-6725 MHz. Based on the preliminary review done by the working group, it appears that candidates for such alternative feeder link bands would be the 3600-3700 MHz and 10.95-11.20/11.45-11.70 MHz bands. The FSS allotment band at 4500-4800 MHz may also be a candidate from a technical and current usage point of view. However, the existence of the FSS Allotment Plan for this band raises significant regulatory and policy issues.

If no suitable feeder link bands below 15 GHz are available, these applicants may be required to amend their applications to specify the use of bands above 15 GHz for feeder links, despite the substantial penalties associated with system design and service concept modification.

4.4 Feeder Links in the 20/30 GHz Bands

4.4.1 MSS Feeder link characteristics (20/30 GHz)

Detailed information on system characteristics and requirements is given in the following sections for each proponent of feeder links in the 20/30 GHz bands. Within this portion of the report, the term LEO is used to identify satellites or systems using the 20/30 GHz Fixed-Satellite Service (FSS) bands for feeder links to low earth orbit mobile-satellite service systems.

The information has been provided to facilitate the analysis of the sharing potential between LEO systems and other services. The spectrum requirements and characteristics given in this section are subject to possible change as a result of the Negotiated Rulemaking, in order to meet the FCC objectives of multiple entry and maximizing US capacity. They also may be subject to change as a result of coordination with other users of the feeder link frequency bands.

4.4.1.1 The Motorola IRIDIUM System

4.4.1.1.1 Description

The IRIDIUM system consists of sixty-six satellites in total: eleven satellites in each of six orbital planes. The orbits are circular with an altitude of 780 km and an inclination of about 86.4 degrees. The six orbital planes are displaced 31.587 degrees in longitude with respect to each other. The satellites in the even numbered planes are offset 16.347 degrees from those in the odd numbered planes. In addition, there is a 1.3 degrees plant to plane phasing of the satellites. The IRIDIUM system is capable of providing worldwide MSS services to appropriate feeder-link gateways.

Feeder-links for IRIDIUM will make use of frequencies in the Ka band (29.1 - 29.3 GHz uplink; 19.4 - 19.6 GHz downlink). This permits relatively small satellite spotbeams to be used to communicate with the feeder-link earth stations. As the satellite moves throughout its orbit, the feeder-link is maintained by tracking antennas both on the ground and on the satellites. Each IRIDIUM satellite has four independently steerable Ka-band feeder-link antennas, which will be used to maintain continuous active operation.

4.4.1.1.2 Spectrum Requirements

The IRIDIUM feeder-link spectrum requirement is 200 MHz in each of the uplink and down link band segments. Twelve 6.25 MHz channels within each band segment have been requested. These channels are on an average 15 MHz centers. The system can operate on 7.5 MHz centers.

4.4.1.1.3 Satellite Antenna Characteristics

Each of the four IRIDIUM feeder-link satellite antennas is independently steerable over the entire visible surface of the globe. The characteristics of the antenna are as follows:

Receive: @ 29.2 GHz
- Polarization: RHCP
- Max. Isotropic Gain: 30.1 dBi
- Noise Temperature: 1295°K
- 3 dB Beamwidth: 5°

Transmit: @ 19.5 GHz
- Polarization: RHCP
- Maximum Isotropic Gain: 26.9 dBi
- Total Peak Power: -3.2 dBW
- Max Power Density: -68.1 dBW/Hz
- 3 dB Beamwidth: 7.4°

4.4.1.1.4 Earth Station Characteristics

The IRIDIUM feeder link gateway Earth stations, which may, within sharing restrictions, be located anywhere in the world, will have the following typical characteristics:

Receiver: @ 19.5 GHz
- Antenna Diameter: 3M
- Maximum Isotropic Gain: 53.2 dB
- Off-Axis Gain: 29-25 logØ
- Beamwidth: 0.36°
- Polarization: RHCP

Transmitter
- Antenna Diameter: 3M
- Maximum isotropic Gain: 56.3 dBi
- Off-Axis Gain: 29-25 logØ
- Beamwidth: 0.24°
- Polarization: RHCP

- Total Peak Power: +12 dBW (rain)
  -12.8 (clear)
- Max. Power Density: -79.2 dBW/Hz (rain)
  -54.4 dBW/Hz (clear

4.4.1.1.5 **Feeder Link Transmission Characteristics**

The IRIDIUM satellite demodulate the service links and direct the signal to the appropriate link; service, inter-satellite, or feeder. This technique minimizes the feeder-link loading. However, system operational traffic will increase the use of the Feeder-links.

4.4.1.2 **The TRW ODYSSEY System**

4.4.1.2.1 **Description**

The ODYSSEY system consists of twelve satellites in total; four satellites in each of three orbit planes. The orbits are circular with an altitude of 10,370 km and an inclination of 56°. The three orbit planes are staggered 120° in longitude with respect to each other. The ODYSSEY system is capable of providing worldwide MSS services to appropriate feeder-link gateways.

Feeder links for ODYSSEY will make use of frequencies in the Ka band (29.5-30.0) GHz uplink; 19.7-20.2 GHz downlink). This permits relatively small satellite spotbeams to be used to communicate with the feeder-link earth stations. As the satellite moves throughout its orbit, the feeder link is maintained by tracking antennas both on the ground and on the satellites. Each ODYSSEY satellite has two independently steerable Ka-band feeder link antennas, which will be used to maintain continuous active operation.

4.4.1.2.2 **Spectrum Requirements**

Within the 500 MHz bandwidth available, the current ODYSSEY feeder link spectrum requirement is for approximately 102 MHz. The upper part of the Ka-band spectrum has been selected for this (29.895-29.997 GHz uplink; 20.095-20.197 GHz downlink).

4.4.1.2.3 **Satellite Antenna Characteristics**

Each of the two ODYSSEY feeder link satellite antennas is independently steerable over the entire visible surface of the globe. The current design of the antenna is as follows.

Polarization: LHC receive; RHC transmit.

3 dB Beamwidth: 2.2° at 29.75 GHz; 3.25° at 19.95 GHz

Peak Gain: 37.5 dBi at 29.75 GHz;
34.0 dBi at 19.95 GHz

Transmit:	34 - 1.136ϕ^2 for 0°< ϕ < 4.196°
	14 for ϕ > 4.196°
Receive:	37.5 - 2.48ϕ^2 for 0° < ϕ < 2.840°
	17.5 for ϕ > 2.840°

4.4.1.2.4 **Earth Station Characteristics**

The ODYSSEY feeder link gateway Earth stations, which may in principle be located anywhere in the world, will have the following typical characteristics:

Antenna Diameter:	3.0 meters
Polarization:	LHC transmit; RHC receive
Pointing Angle Range:	360° azimuth; 10° to 90° elevation
3 dB Beamwidth:	0.25° at 29.75 GHz; 0.38° at 19.95 GHz
Peak Gain:	57.6 dBi at 29,75 GHz; 54.1 dBi at 19,.95 GHz
Off-Axis Gain:	32-25log(ϕ) dBi for 1° < ϕ < 48°, and -10 dBi for 48° < ϕ < 180°

4.4.1.2.5 **Feeder Link Transmission Characteristics**

The ODYSSEY satellites use "simple frequency-changing transponders" (IFRB terminology). The signals received or transmitted from each service link beam (of which there are currently 19 beams in total) are frequency translated (by a conversion frequency that is unique to each service link beam) to the appropriate frequency for the feeder link. Thus the feeder link bandwidth requirement (ignoring any frequency re-use by orthogonal polarization) is equal to the product of the RF bandwidth used within each service link beam and the number of service link beams.

4.4.2 **27.5-30 GHz Uplinks**

This section discusses sharing issues for feeder link spectrum proposed for use by several Low Earth Orbit Satellite Systems. It has two parts. Section 4.4.2.1 concerns issues in the band 28.5-29.5 GHz. Section 4.4.2.2 concerns feeder link issues in the bands 29.5-3.0 GHz. Use of the band 27.5-28.5 GHz is similar to the 28.5-29.5 GHz band, but there are no applicants for the lower band.

A graph of the international allocations (Post-WARC-92) for Region 2 is shown in Figure 4.4.2-1 for the 27.5 - 30.0 GHz band. Also shown in the figure are the frequency bands requested by two LEO systems and the bands occupied by two other users of this portion of the spectrum. Fixed-satellite networks which are operating in the 20/30 GHz band or proposed for operation include several different types of Fixed service and fixed-satellite service systems. These would include VSATs, high data rate FSS uplinks, feeder links to geostationary satellites in other services such as MSS and ISS, and the currently proposed feeder links to LEO satellites. Typical transmitting Earth station characteristics for FSS systems are given in Figure 4.4.2-2. Typical receiving space station characteristics are given in Figure 4.4.2-3.

The fixed service, as currently allocated within the United States would include conventional point-to-point systems. A new use for a portion band has been proposed recently and is the subject of a separate Notice of Proposed Rulemaking (NPRM), CC Docket No. 92-297. This new service is a Local Multipoint Distribution Service (LMDS) and would be used for distributing TV signals. Typical characteristics of an LMDS system are given in Figure 4.4.2.1.2-1.

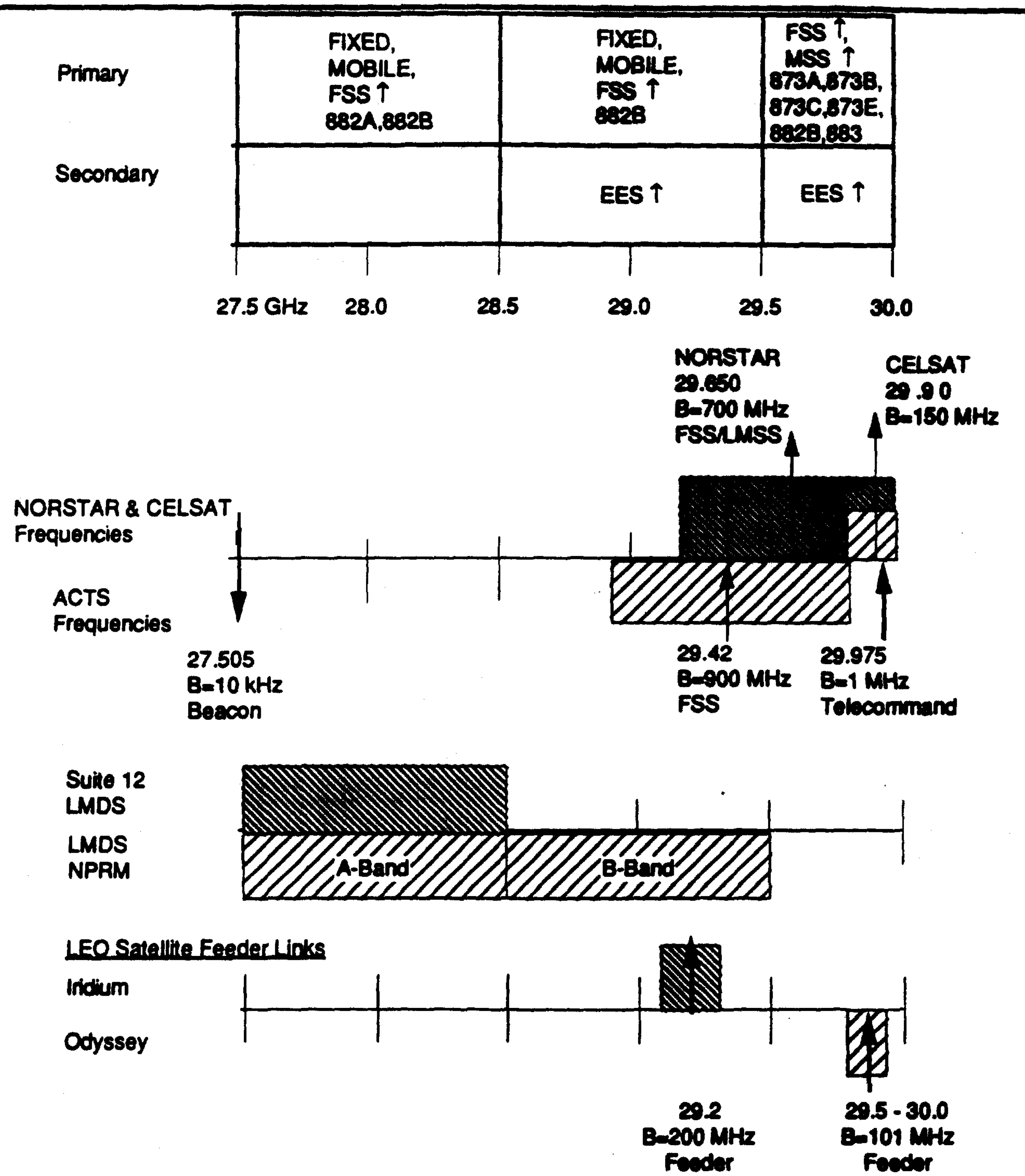

Figure 4.4.2-1. Region 2 allocations and other users of the 27.5-30.0 GHz band

System	Orbit Long	Toler	Frequency Band (MHz)	Type	Pe	Gain	Polar	Radiat'n Pattern
ACTS	-100	0.05	28,970.00 - 29,870.00	LBR	-55.3	55.5	-	App 28
ACTS	-100	0.05	28,970.00 - 29,870.00	NGS	-59.3	60.7	-	App 28
ACTS	-100	0.05	29,974.50 - 29,975.50	CR&T	-43.0	60.8	-	App 28
L-SAT	-19.0	0.1	28,052.00 - 28,700.00	FSS	-36.0	70.0	-	Rec 465
L-SAT	-19.0	0.1	28,052.00 - 28,700.00	FSS	-36.0	70.0	-	Rec 465
ITALSAT	13.0	0.1	28,215.00 - 29,997.00	FSS	-40.0	61.9	-	Rec 465
ITALSAT	13.0	0.1	28,215.00 - 29,997.00	FSS	-40.0	61.9	-	Rec 465
EDRSS		0.1	27,500.00 - 30,000.00	FSS	-40.0	69.0	-	Rec 465
ETS-6-FS	154.0	0.5	27,500.00 - 31,000.00	FSS	-44.0	60.9	-	Rec 465
F-SAT		0.2	29,500.00 - 30,000.00	FSS	-30.0	59.0	-	App 28
CS-2A, 2B CS-3A, 3B		0.1	27,500.00 - 29,000.00	FSS	-40.7	68.9	LHC	Rec 465
SCS-1		0.1	27,570.00 - 29,000.00	FSS	-31.2	61.1	LHC	Rec 465
NORSTAR I	90.0	0.05	29,300.00 - 30,000.00	FSS, LMSS	-10.5			
IRIDIUM	755*	-	29,100.00 - 29,300.00	FSS	-54.4	57.6	-	
IRIDIUM	755*	-	29,100.00 - 29,300.00	FSS	-79.2	57.6	-	
ODYSSEY	0,371*	-	29,500.00 - 30,000.00	FSS	-47.0	57.57	-	
SUPERBIRD		0.1	27,570.00 - 29,120.00	FSS	-33.4	61.1	LHC	Rec 465

* Altitude in km (non-geostationary satellite)
It should be noted that some of the above systems would operate above 29.5 GHz. The corresponding downlink at 19.7-20.2 GHz does not have a pfd limit and so the characteristics of these systems may be different from those operating below 29.5 GHz.

Figure 4.4.2-2. Transmitting Earth station characteristics - 30 GHz band

System	Orbit Long	Long Toler	Frequency Band (MHz)	Polar	Beam Type	Gain	Ts
ACTS	-100.0	0.05	28,970.00 - 29,870.00	-	East/West	53.1	920
ACTS	-100.0	0.05	28,970.00 - 29,870.00	-	Steerable	43.3	920
ACTS	-100.0	0.05	29,974.50 - 29,975.50	-	Ka CR&T	34.0	3820
L-SAT	-19.0	0.1	28,052.00 - 28,700.00	-	FSS	44.0	630
ITALSAT	13.0	0.1	28,215.00 - 29,997.00	-	FSS	53.0	1300
EDRSS		0.1	27,500.00 - 30,000.00	-	FSS	41.0	1585
ETS-6-FS	154.0	0.5	27,500.00 - 31,000.00	-	FSS	52.0	922
CS-2A, 2B CS-3A, 3B		0.1	27,500.00 - 29,000.00	LHC	FSS	39.6	2327
SCS-1		0.1	27,570.00 - 29,000.00	LHC	FSS	49.0	1330
NORSTAR I	-90.0	0.05	29,300.00 - 30,000.00		FSS,LMSS	45.0	2000
IRIDIUM	755*		29,100.00 - 29,300.00	-	FSS	23.5	1453
ODYSSEY	10,371*		29,500.00 - 30,000.00	-	FSS	32.0	630
SUPERBIRD		0.05	27,570.00 - 29,120.00	LHC	FSS	49.0	1330

* Altitude in km (non-geostationary satellite)

Figure 4.4.2-3. Receiving Space Station Characteristics - 30 GHz band

4.4.2.1 <u>Sharing Issues in the 28.5-29.5 GHz band (Uplink)</u>

Figure 4.4.2-1 depicts the existing and proposed uses of the allocation 28.5-29.5 GHz. The principal LEO feeder link of concern is the proposed 200 MHz uplink, of the IRIDIUM system at 29.1-29.3 GHz, described above. It overlaps the spectrum proposed for use by the uplink to the geostationary ACTS satellite, 28.9-29.8 GHz, and the B-Band of the LMDS service proposed in a recent FCC NPRM. The potential interference paths which need to be addressed are as follows:

*a. From the LEO feeder transmitter to the LMDS subscriber receiver;

*a1. From the LEO feeder transmitter to the HUB subscriber receiver;

*b. From the LEO Feeder to geostationary FSS satellite receiver

*c. From LMDS to LEO satellite receiver

*d. From FSS earth station to LEO sat. receiver

e. From LMDS to FSS satellite receiver

f. From FSS earth station to LMDS receiver

The interference paths of principal concern to this proceeding are those involving the LEO Feeder links, denoted by an asterisk, "*", above.

4.4.2.1.1 Sharing with the fixed-satellite service (28.5-29.5 GHz)

This topic covers two cases of interference geometry. Case 1, Figure 4.4.2.1.1-1, is the avoidance of illumination of the GSO Satellite. Case 2. Figure 4.4.2.1.1-1, is the minimization of the interference caused by FSS(GSO) uplinks into the LEO satellite.

These two cases have several common avoidance options as discussed below. Additional options specific to the particular case are discussed in the subsections to this section.

There are five options available, of which three are common to both cases (c, d and e) :

a) System coordination (case specific)

b) Geographic isolation (case specific)

c) Switching of a LEO Gateway path from one satellite to another

d) Use of an alternate Gateway (via land line)

e) Acceptance of short term outages.

Option c)

Switching to an alternate LEO satellite is possible to avoid harmful interference because a constellation with inter-satellite links can receive uplink traffic at any satellite.

When harmful interference is possible, the system can switch to an alternate satellite providing that one is in view. The interference is avoided when this option is available.

Two or more satellites are always in view for the IRIDIUM system if the Gateways are above about 52° latitude. Below that latitude, the location of the FSS(GSO) satellite relative to the LEO earth station must be considered. Only when the gateway is near the equator does the probability of the unavailability of a second satellite become significant. Generally, the joint probability of the FSS(GSO) satellite being in the interference cone and an alternate LEO satellite is not available is extremely low.

Option d)

A telephone trunk to process traffic through another gateway may be used during the period of link shut down. The problem is again avoided when this option is available.

Option e)

A system operator may decide to shut down the link for a few seconds to prevent interference. During this period, the subscribers could be notified to standby. This is particularly attractive near the equator where the interference zone is overhead and, therefore, the transit time is minimal. Extreme measures methods to keep the link operational may not be desirable.

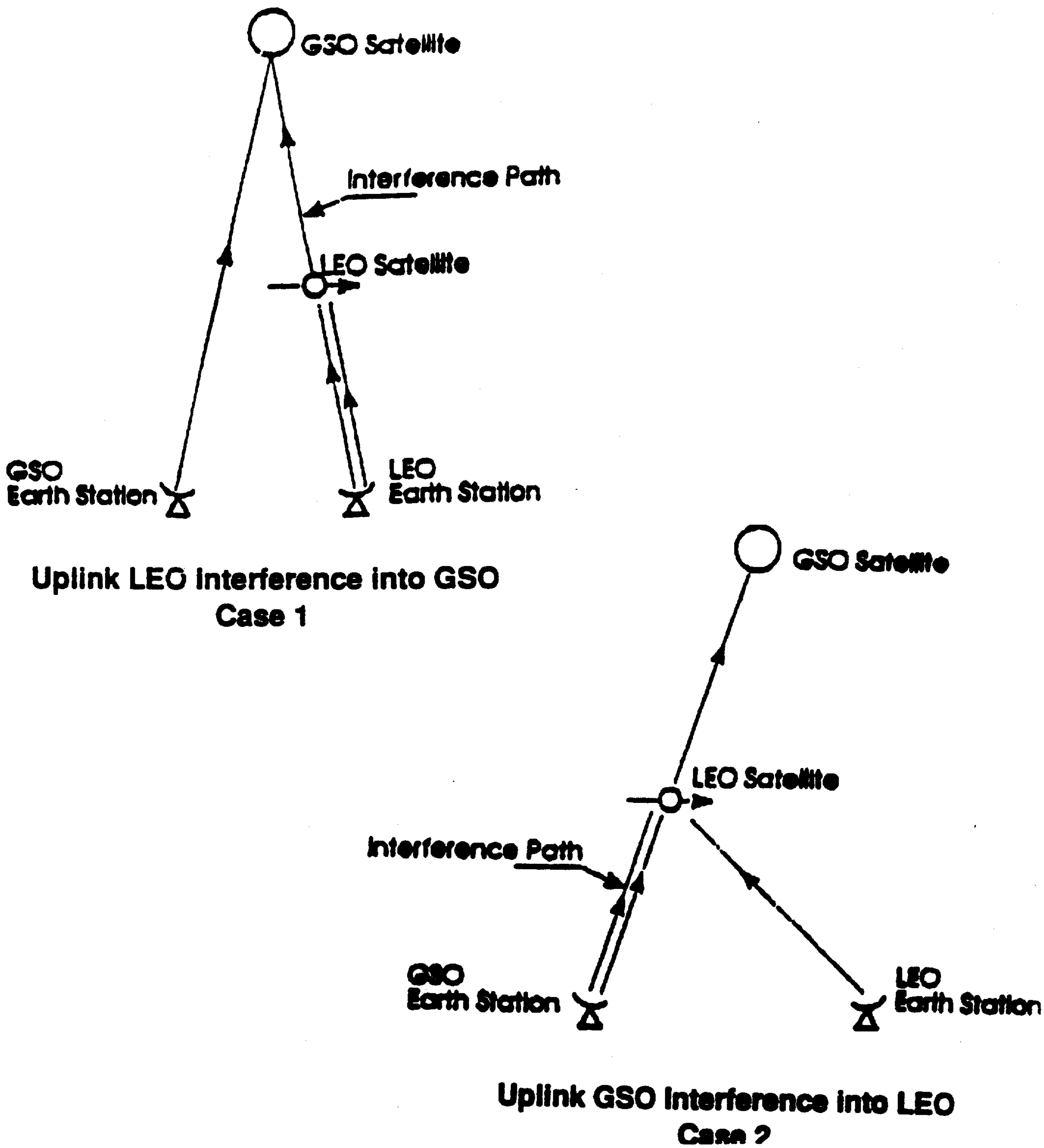

Figure 4.4.2.1.1-1 Uplink Interference cases

4.4.2.1.1.1 Interference from transmitting FSS earth stations to MSS satellite receivers

The worst case interference condition occurs when the main beam of the FSS(GSO) earth station is pointed at the LEO satellite. This configuration is Case 2 (Figure 4.4.2.1.1-1). There is a low probability of this occurrence (see paragraph 4.1.2).

First it must be determined if there is sufficient energy arriving at the LEO satellite to cause harmful interference. The maximum power-flux density incident at a geostationary satellite due to emissions from a GSO earth terminal can be determined by using the following simple example:

FSS(GSO) earth station eirp	94.0 dBW/MHz
Spreading Loss	
(898.6 km range, 780 km altitude)	-130.1 dB/m^2
PFD at LEO	-69.9 dBW/m^2/MHz

This level is greater than a non-interference level and, therefore, an acceptable option to avoid interference should be exercised.

There are five options available, of which three are common to both cases (c, d and e) :

a) System coordination (case specific)

b) Geographic isolation (case specific)

c) Switching of a LEO Gateway path from one satellite to another

d) Use of an alternate Gateway (via land line)

e) Acceptance of short term outages.

Options c, d and e were discussed in section 4.4.2.1.1

Option a)

Since all FSS(GSO) earth stations are not operating at maximum power, it may be possible to accept the uplink interference. This needs to be examined on a case by case basis. Existing FSS(GSO) earth stations will need to be taken into account in the coordinating process. Subsequently, any new FSS(GSO) earth stations will need to coordinate with all existing FSS earth stations including LEO.

Option b)

The signal level into the LEO satellite receiver is reduced by the off-axis gain of the LEO satellite antenna. In coordinating the LEO system with existing FSS(GSO) earth stations, an appropriate geographic isolation area around the LEO earth station can be determined. If this area is avoided by FSS(GSO) earth stations, then the required isolation from FSS(GSO) earth station transmissions is achieved. Subsequent FSS(GSO) earth station applications would avoid locating earth stations in this area.

4.4.2.1.1.2 **Interference from transmitting LEO earth stations to FSS(GSO) satellite receivers**

The worst case interference condition occurs when the main beam of the LEO earth station is pointed at the GSO satellite. This configuration is shown as Case 1 in Figure 4.2.1.1-1. There is a low probability of this occurrence (see paragraph 4.1.2).

First it must be determined if there is sufficient energy arriving at the GSO satellite to cause harmful interference. The maximum power-flux density incident at a geostationary satellite due to emissions from a LEO earth station can be determined by use of a simple example:

LEO earth station xmtr power	-18.2	dBW/MHz
LEO earth station antenna gain	57.6	dBi
Spreading Loss (35,858 km)	-162.1	dB/m^2
PFD at GSO	-122.7	dBW/m^2/MHz

Since this level may be greater than a non-interference level, an acceptable option to prevent interference should be exercised.

There are five options available, of which three are common to both cases (c, d and e) :

a) System coordination (case specific)

b) Geographic isolation (case specific)

c) Switching of a LEO Gateway path from one satellite to another

d) Use of an alternate Gateway (via land line)

e) Acceptance of short term outages. Options c, d and e were discussed in 4.4.2.1.1

Options c, d and e were discussed in 4.4.2.1.1

Option a)

Because of the brief periods that this condition exists, it may be possible to coordinate with the FSS(GSO) system.

Option b)

Not available

4.4.2.1.2 <u>Sharing/Coordination with LMDS</u>

In CC Docket No. 92-297, the FCC has issued an NPRM that proposes rules to establish the so-called Local Multipoint Distribution Service ("LMDS") in the frequency bands 27.5-29.5 GHz. The FCC's LMDS proposal (which includes a domestic U.S. reallocation of spectrum to the LMDS and associated service rules) would accommodate a cellular-like terrestrial system with groups of millimeter wave stations collecting broadcast FM video with small antennas mounted on user subscriber homes and businesses. The signals would be broadcast from hubs spaced 12 miles apart on a grid. They would operate in two separate bands of 1000 MHz (at 27.5-28.5 GHz and 28.5-29.5 GHz). Each 1000 MHz band would be divided into 50 channels of 20 MHz each, and the each 20 MHz channel would be further subdivided into an 18 MHz segment (for broadcast video) and a 2 MHz segment (available for two-way conversation and/or data between the user subscriber and the hub.

The anticipated LMDS baseline assumes that the two-way channels would consist of 30 kHz FM channels similar to analog cellular. Frequency reuse between cells would be achieved by alternating the hub's vertical and horizontal polarization for the video and broadcast channels. The forward narrow band link to each subscriber would be cross-polarized with the video transmissions.

The 2000 MHz of spectrum proposed for allocation to the LMDS are allocated on a co-primary basis in the United States to the Fixed Service and the Fixed-Satellite Service. The FSS allocation also covers the contiguous 29.5-30 GHz band (on a shared co-primary basis in the U.S. with the Mobile-Satellite Service). The 2500 MHz allocation to FSS at 27.5-30.0 GHz (Earth-to-space) is paired with the 2500 GHz allocation at 17.7-20.2 GHz for space-to-Earth transmissions.

Although the FCC correctly noted in its LMDS NPRM that the 27.5-29.5 GHz band is not presently used for FSS transmissions, the allocation's current fallowness is fully consistent with what was envisioned when the spectrum was initially allocated to the FSS by the ITU. The Ka-Band FSS allocations were intended essentially as an expansion band for future FSS services.

Ironically, the FCC's LMDS proposal was thrust upon the scene just as the contemplated FSS services are now beginning to materialize in increasing numbers. This Working Group believes that FSS access to the full 2000 MHz at 27.5-29.5 GHz is already necessary to satisfy this increasing demand from commercial satellite operators.

In this regard, NASA will begin the commercialization of the Ka-Band in a matter of months with the launch of the Advanced Communications Technology Satellite ("ACTS"); Norris Satellite Communications, Inc., which was authorized last year to build an FSS satellite to operate at 29.5-30 GHz for uplinks, recently applied to extend its uplink authorization to include the 29.3-29.5 GHz band; and two of the MSS/RDSS applicants -- Motorola and TRW --currently propose to use 200 MHz and approximately 100 MHz respectively of the Ka-Band FSS allocation at 27.5-30 GHz for feeder links. In addition, countries around the world are developing Ka-Band satellite systems that would use the frequencies proposed for LMDS for FSS services.

As shown below with regard to the IRIDIUM feeder links at 29.1-29.3 GHz, and as independently concluded by NASA (in its comments to the FCC in CC Docket No. 92-297) for the Ka-Band FSS service in general, FSS systems and LMDS systems are unlikely to be able to operate compatibly in the same bandwidth. Because LMDS systems would operate across the entire 27.5-29.5 GHz band, and because the urban areas that are economically desirable for LMDS services are the same areas that are desirable for FSS applications, sharing between FSS and LMDS on the basis of either frequency separation or geographic separation appears not to be feasible. Similarly, sharing on the basis of either antenna off-axis discrimination or polarization discrimination also does not appear to be feasible.

In effect, the FCC's LMDS proposal, if implemented in its current form, would preempt the co-primary FSS service (including the feeder link operations authorized for FSS allocations that are contemplated by Motorola) from 2000 MHz of its 2500 MHz allocation. This would also eviscerate FSS's ability to utilize the corresponding downlink allocation at 17.7-19.7 GHz.

The Working Group believes that the FCC did not adequately consider the impact that its LMDS proposal would have on the FSS in general or on the proposed MSS/RDSS system feeder link operations in the Ka-Band FSS allocations. It urges the FCC to reevaluate its LMDS proposal in light of the impact its implementation would have on the future of the FSS.

Of particular relevance to the work of this Working Group is the fact that the IRIDIUM system proposes to utilize the 29.1-29.3 GHz band for its feeder links. The IRIDIUM system proposes to locate gateway feeder link stations in the United States, and must do so in a way that permits economical connection to a local PSTN. Motorola plans two groups of stations in the U.S., and each group will consist of up to three Ka-Band transmitters that will be transmitting in the 29.1-29.3 GHz band with narrow beam circularly polarized antennas. The stations will track and be tracked by satellites from a minimum of 9° above horizon through the orbital path on each pass. More than one satellite will be tracked by the group at a time.

With regard at least to Motorola's feeder link (i.e., FSS) proposal, two interference issues must be examined to determine the possibility that spectrum can be shared between IRIDIUM feeder links and the LMDS:

(a) Interference from LMDS into the satellite receivers; and

(b) Interference from IRIDIUM gateway sidelobes into the LMDS system.

Each of these issues is discussed below, and the conclusion to be drawn is that co-frequency sharing between IRIDIUM and the LMDS is not practical.

4.4.2.1.2.1 Interference from LMDS to Iridium LEO satellite receivers

The IRIDIUM LEO satellite has a receiver noise floor of -197 dBW/Hz on the feeder uplink. The Suite 12 hub antennas have low gain (10 dB) in the vertical plane suggesting a half power beamwidth of about 60 degree or 30 degree above the horizontal plane. Therefore, the maximum probability for interference from a collection of LMDS stations is when the satellite is moderately low on the horizon and a feeder Gateway station is located near the metropolitan area containing the LMDS hub stations. In this scenario, the hubs omni antennas couple tightly with the satellite uplink beam with an average gain of at least 7 dB. With the hubs planned for 12 mile grids then each hub would cover 113 square miles of territory. An IRIDIUM spot beam would cover about 2800 square miles and therefore be subjected to uplink interference power from 25 hubs at a time whenever a Gateway station is located in the same metropolitan area.

Table 4.4.2.1.2-1 is a calculation of the uplink interference power into an IRIDIUM satellite receiver. As can be seen the Suite 12 network of hub stations, would add a measurable amount of interference noise into a LEO satellite co-sharing this frequency band even using nominal link parameters.